Heuristic for real-time train rescheduling and local rerouting

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During the last decades, there has been a growing interest in public transport, increasing the importance for accurate trains. Though timetabling can account for possible delays, in practice, external events regularly lead to primary and secondary delays. Once trains start deviating from their original schedule, conflicts are detected. Conflicts need to be resolved quickly in a way that disturbs the system as little as possible. Therefore, the impact on the whole network should be taken into account when preventing conflicts. In order to prevent conflicts, an advanced train management system (TMS), including train movement prediction, conflict detection and conflict prevention, is required to increase the accuracy of the rail network. Train movement prediction and conflict detection are already included in some advanced software. However, a good conflict prevention module is not present for practical use. This paper tries to complete this advanced software by including a good conflict prevention strategy.

Recently, many research has been devoted to real-time railway traffic management and thus conflict prevention. Some advanced optimization problems have been proposed to tackle the problem (e.g. [1], [2]). However, most of them lack the practical relevance of a closed-loop environment, indicating the optimization problems are not capable of including updated information during their running time. In [1] and [3], an outline of a complete TMS is discussed, but it has not been implemented in practice yet. In our paper, the focus is only on conflict prevention, since a conflict detection module is currently being implemented in Belgium.

The study area considered in this paper is Brugge-Gent-Denderleeuw, a large part of Flanders in Belgium. This area is approximately 91 km long and 32 km wide, consisting of 84 station areas ensuring 232 different platforms and 8850 block sections. The largest stations in this study area are Gent-Sint-Pieters, Oostende and Brugge. Note that the study area also includes shunt yards. The simulation considers trains between 6 and 7 in the morning, covering both passenger and freight trains, inducing a total of 181 trains. All data was delivered by the Belgian railway infrastructure manager Infrabel. For each delay scenario, 25 simulation runs are executed, each comparing different conflict prevention techniques. Each delay scenario introduces a random delay for α % of all trains. This random delay is taken from the exponential distribution with an average of three minutes and a maximum of fifteen minutes.

This paper introduces a heuristic conflict prevention strategy including rescheduling and local rerouting. If a conflict is detected in a station area, the rerouting optimization procedure is started. This procedure will look for alternative routings through the station area in which the conflict was detected. This subproblem starts at the moment that the first of the conflicting trains enters the station area and ends when both trains have left the station area. For every train entering this station area during the outlined time period, alternative routes are considered, one per platform track. If a train has already entered the station area, its route is fixed and no alternative routes should be considered. The optimization problem is based on a flexible job-shop problem and solved optimally by IBM ILOG Cplex. If rerouting does not deliver a better solution in terms of secondary delays, the original routes are kept.

If the original conflict still exists after solving this routing subproblem, or when the conflict takes place outside a station area, rescheduling is considered in a heuristic way: when a conflict between two trains is predicted, it should be decided which of both trains will be delayed (extra) in order to give priority to the other train. Therefore, two possible situations need to be evaluated and compared. Consider two trains A and B that cause a conflict. First, train A is given priority and gets to use the block section first. This immediately implies that train B is delayed. Subsequently the progress of train A and B is examined. Specifically the duration of extra 'secondary' conflicts that train A (or B) will cause during the next hour are summed up. The sum of secondary conflicts caused by giving A priority over B is then compared to the situation where B is given priority over A. The decision that generates the least seconds of extra 'secondary' conflicts is executed. In order to limit the computation time to determine this decision, only secondary conflicts are considered, involving trains A and/or B, and no further conflicts. Results show improvements compared to a reference FCFS strategy of 2 % (for the delay scenario 20%) up to 8 % (for the delay scenario 80%). The heuristic is further extended to deal with multiple conflicts at once. However, results do not show significant improvements when dealing with multiple conflicts simultaneously.

References

[1] Corman, F., and Quaglietta, E., *Closing the loop in real-time railway control: Framework design and impacts on operations*, Transportation Research Part C, 54 (2015), pp. 15–39.

[2] Pellegrini, P., Marlière, G., and Rodriguez, J., *A detailed analysis of the actual impact of real-time railway traffic management optimization*, Journal of Rail Transport Planning & Management, 6.1 (2016), pp. 1–19.

[3] Quaglietta, E., Pellegrini, P., Goverde, R. M. P., Albrecht, T., Jaekel, B., Marlière, G., Rodriguez, J., Dollevoet, T., Ambrogio, B., Carcasole, D., Giaroli, M. and Nicholson, G., *The ON-TIME real-time railway traffic management framework: A proof-of-concept using a scalable standardised data communication architecture*, Transportation Research Part C: Emerging Technologies, 63 (2016), pp. 23–50.